

## INTRODUCTION

- The purpose of this research is to investigate the changes in a helmet's ability to attenuate impact energy after repeated impacts.<sup>1,2</sup>
- Youth football helmets are of particular interest as the vast majority of current research focuses on helmets for the professional and collegiate levels.<sup>3</sup>
- Ultimately, data from this study can be used to draw conclusions regarding the padding recovery time and the optimal waiting period between impacts, both in sports gameplay and in laboratory testing settings.

## MATERIALS & METHODS

- Three youth football helmets (Schutt Youth Air Standard III, Riddell Revolution Speed Youth, Xenith X2E Youth) and two adult lacrosse helmets (Schutt Stallion, Cascade CPX-R) were placed on an Anthropomorphic Test Device (ATD) headform and neckform.
- Headforms were instrumented with accelerometers and angular rate sensors to measure head Center of Gravity (CG) kinematics.
- Helmets were repeatedly impacted via pneumatic ram at 3.75 m/s. Tests for each helmet included 5 impacts at 3 minute intervals from 2 impact directions (side & rear).
- Kinematic data was used to determine the probability of brain injury based on the Brain Injury Criteria (BrIC) and the Head Injury Criteria (HIC).
- BrIC utilizes maximum rotational velocities to predict brain injury by correlating experimental testing to head & brain finite element models.<sup>4</sup>
- HIC was originally developed to assess risk of skull fracture in automobile crashes and is widely used in injury biomechanics research.<sup>3</sup>

## RESULTS & DISCUSSION

- ANOVA tests were completed for resultant linear acceleration and resultant angular velocity. Results are shown in table 1.

Table 1: ANOVA Test Data

Resultant Linear Acceleration				
Direction of Impact	Lacrosse Helmet	p Value	Football Helmet	p Value
Rear	Schutt Stallion	<b>0.0419</b>	Riddell	0.4425
	Cascade	0.9632	Schutt	0.9487
			Xenith	0.9993
Side	Schutt Stallion	0.7388	Riddell	0.8135
	Cascade	0.5435	Schutt	0.9110
			Xenith	0.7754

Resultant Angular Velocity				
Direction of Impact	Lacrosse Helmet	p Value	Football Helmet	p Value
Rear	Schutt Stallion	<b>0.0176</b>	Riddell	<b>0.0222</b>
	Cascade	0.6011	Schutt	0.4678
			Xenith	0.9975
Side	Schutt Stallion	0.7644	Riddell	0.8064
	Cascade	0.3506	Schutt	0.4498
			Xenith	0.3660

### Limitations:

- The delay between impacts may not represent some real time gameplay impacts.
- There were some variations in impact speeds ( $\pm 1$  m/s).
- The behaviors of the ATD's do not perfectly model real life biomechanical reactions.

## CONCLUSIONS

- This study showed that in most cases repeated impacts did not have a significant effect on a helmet's ability to attenuate impact energies.
- Lacrosse helmets showed more variation in kinematic responses when compared to football helmets.
- Future steps for this study include expanding the test procedure to include more repeat impacts and shorter delays between impacts.
- For the helmets that are affected by repeated impacts, the padding components should be studied for improvement.

### REFERENCES CITED

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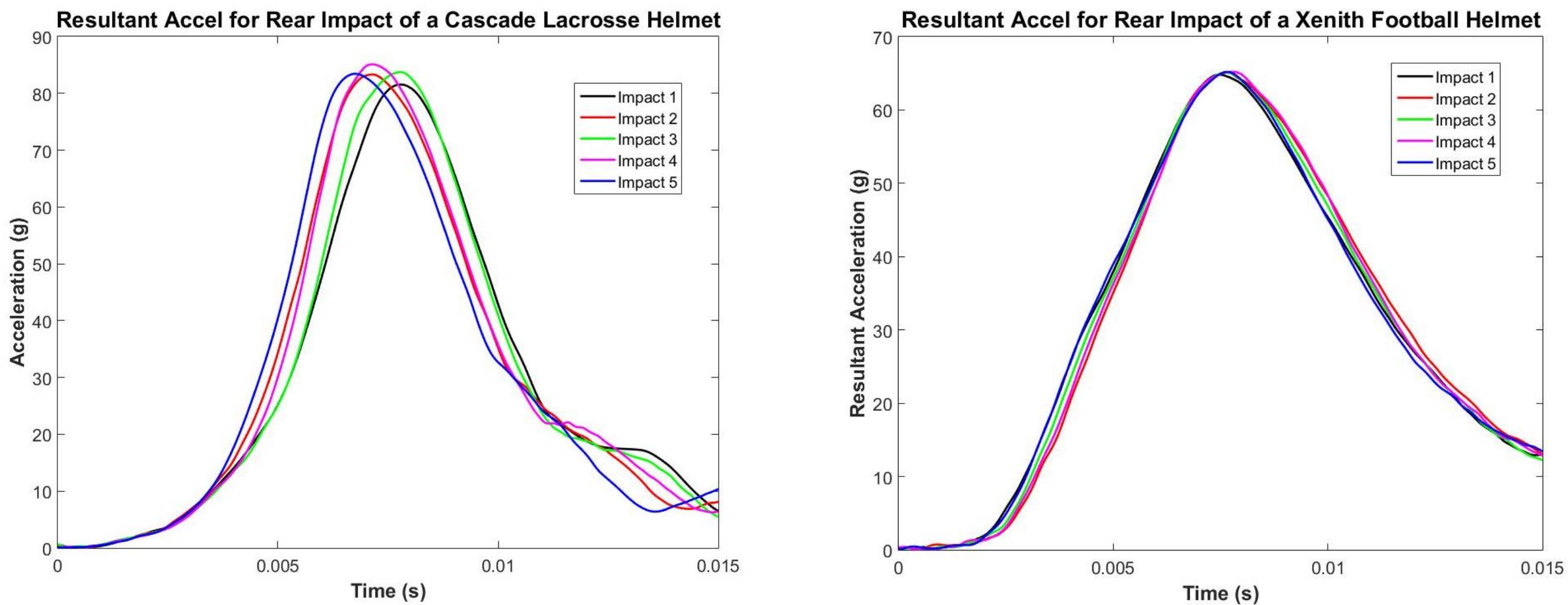


Figure 3: Resultant Accelerations for Football and Lacrosse Helmets

$$BrIC = \sqrt{\left(\frac{\omega_x}{\omega_{xC}}\right)^2 + \left(\frac{\omega_y}{\omega_{yC}}\right)^2 + \left(\frac{\omega_z}{\omega_{zC}}\right)^2}$$

Equation 1: Brain Injury Criteria Equation

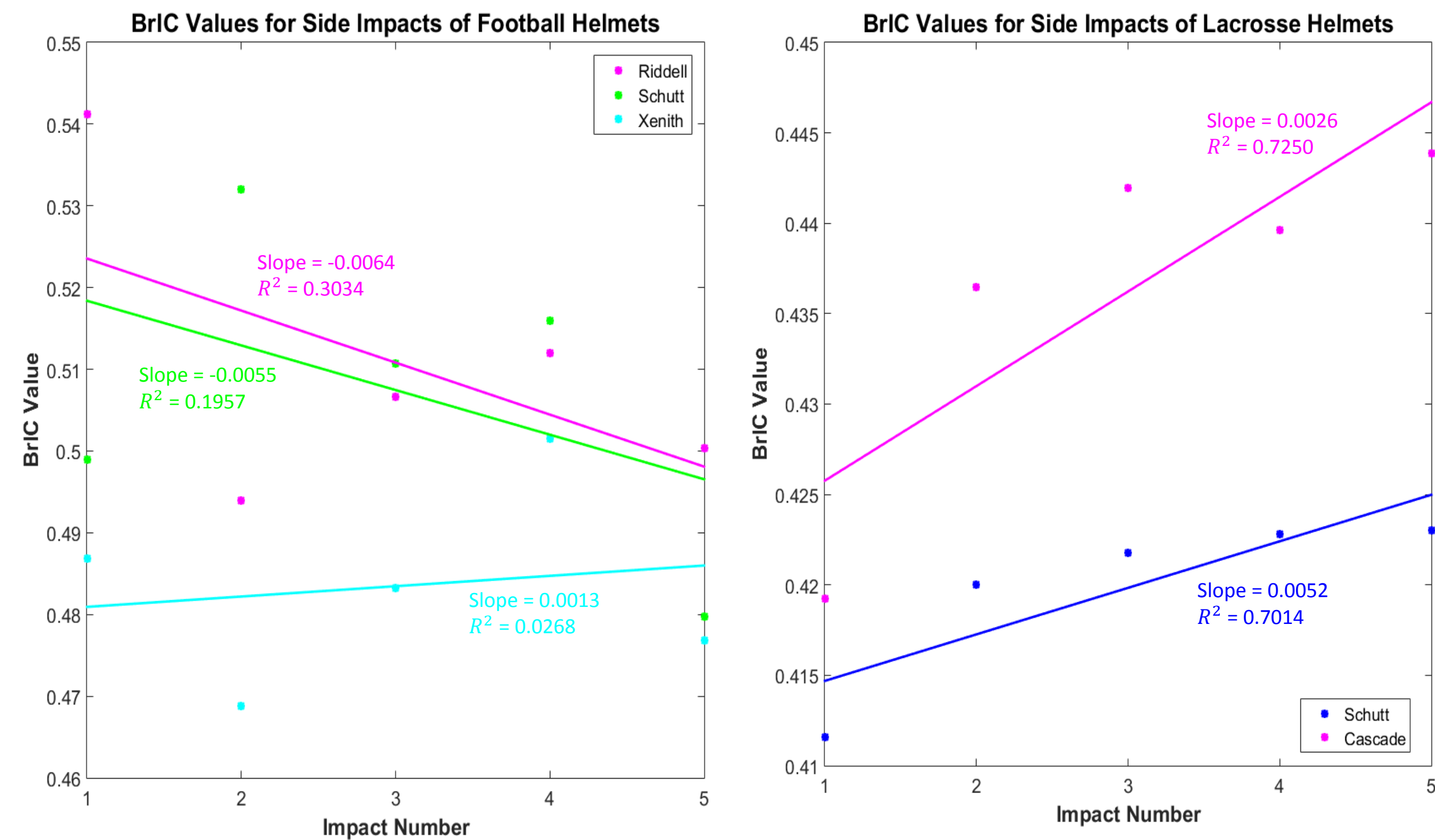


Figure 4: BrIC Values for Football and Lacrosse Helmets

$$HIC = \max \left( (t - t_0) \left[ \left( \frac{1}{t - t_0} \right) \int_{t_0}^t a(t) dt \right]^{2.5} \right)$$

Equation 1: Head Injury Criteria Equation

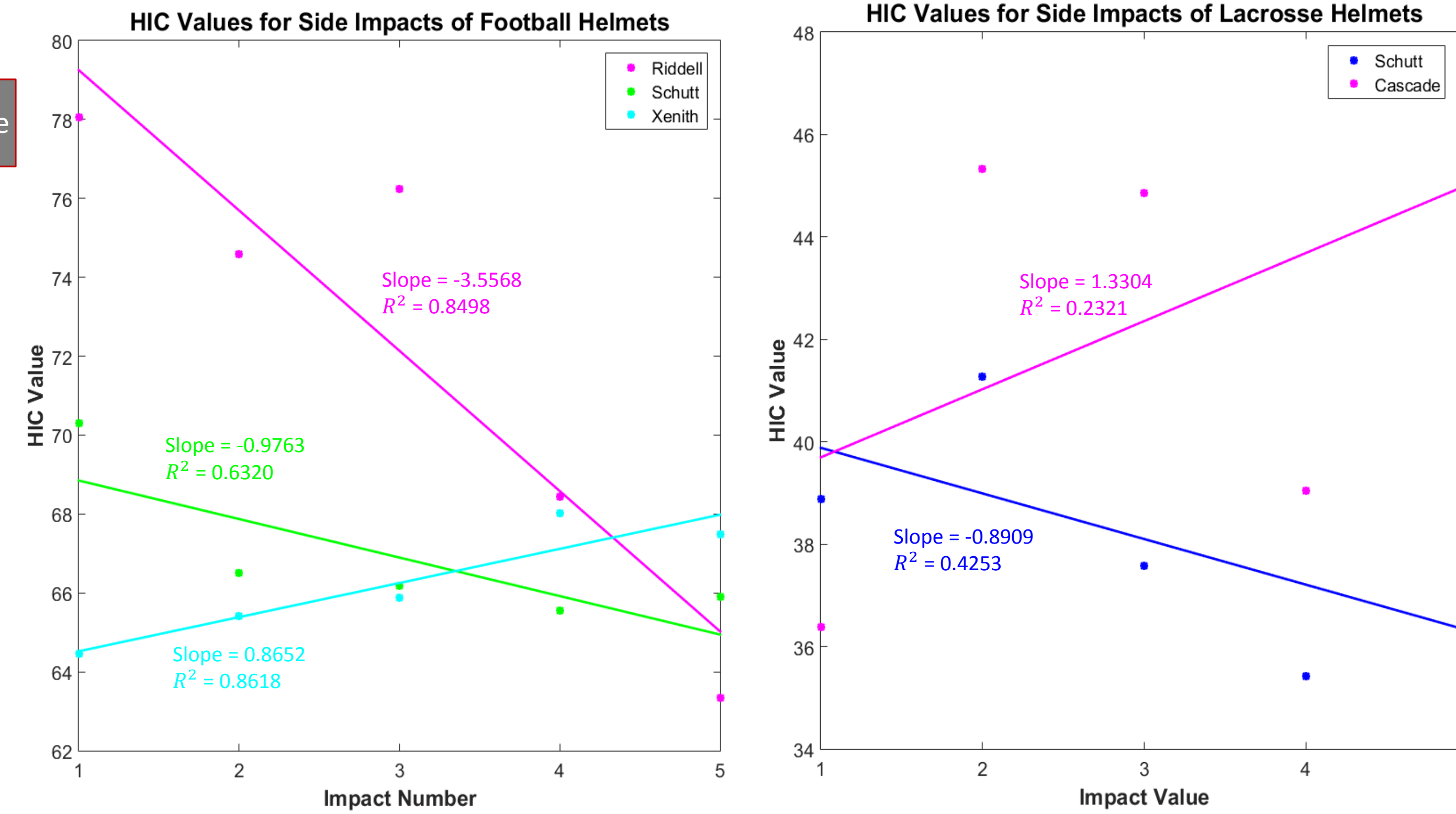


Figure 5: HIC Values for Football and Lacrosse Helmets

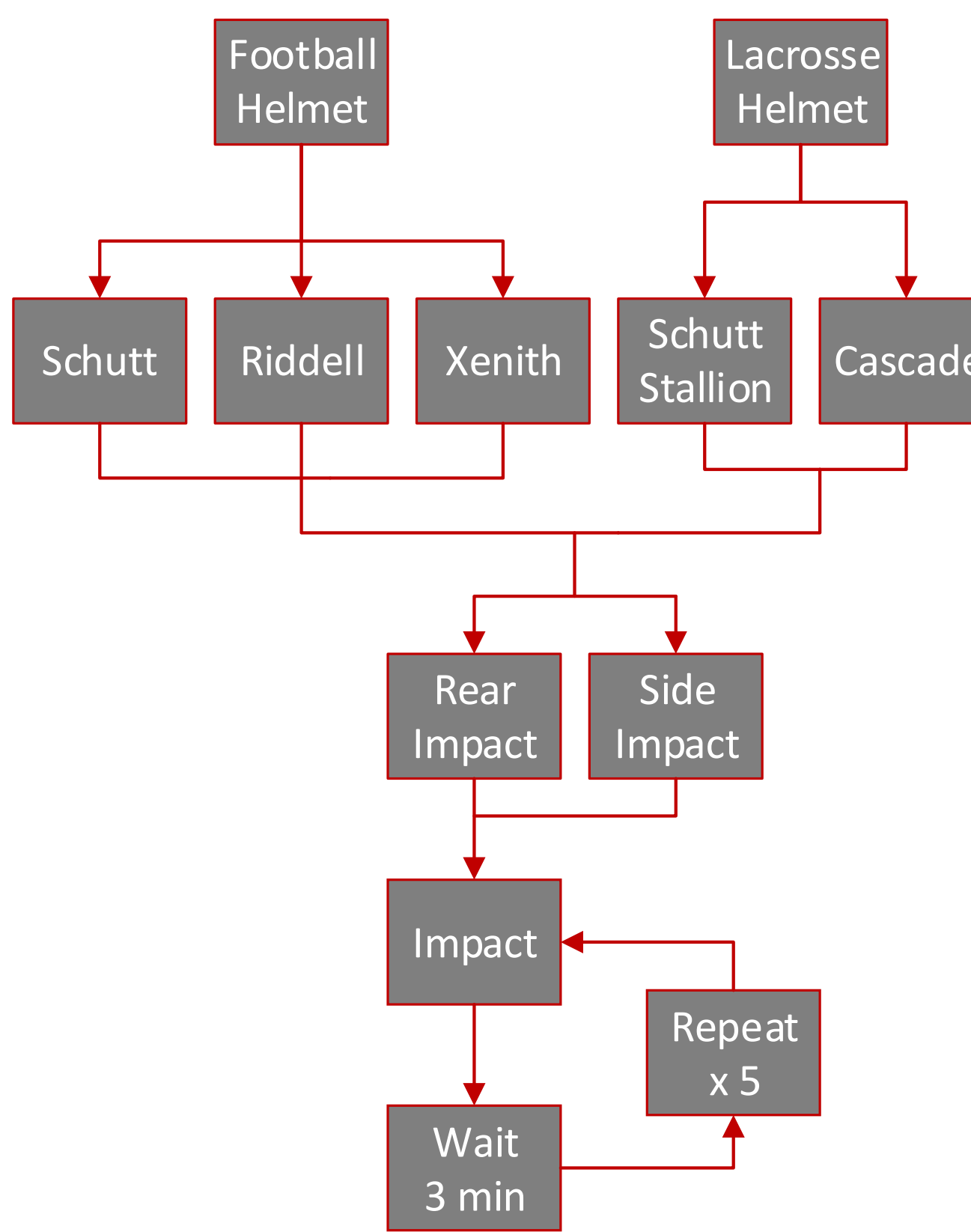


Figure 2: Testing flowchart

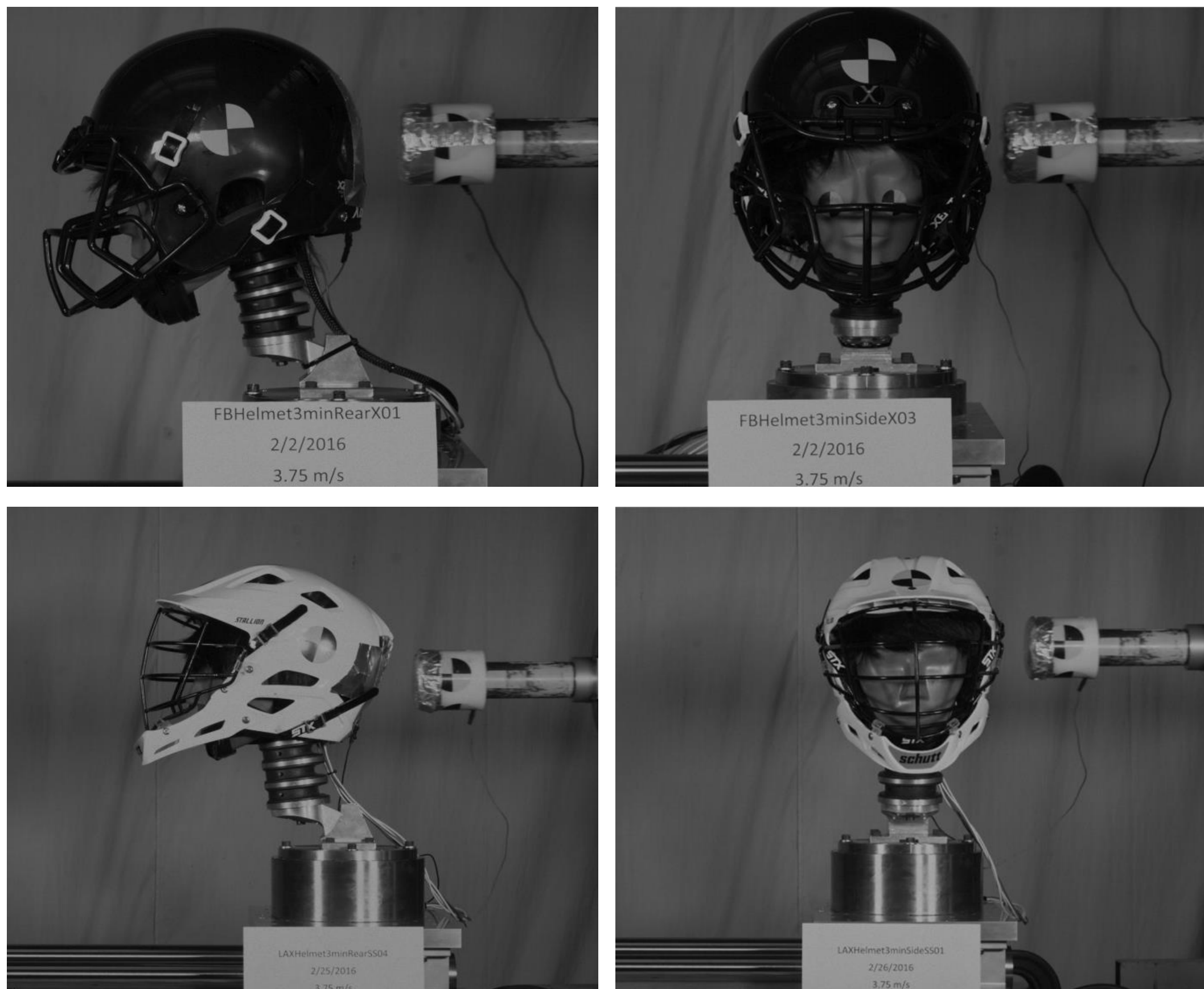


Figure 1: Test setup